A MEGAFOSSIL FLORA FROM THE EOCENE OF GOLDEN GROVE, SOUTH AUSTRALIA

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Summary

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A new Eocene plant megafossil locality is reported from near Golden Grove, South Australia. Well preserved mummified leaves, fruits and flowers and impressions are abundant in a lens structure within the East Yatala Sand Pit operated by Monier. Preliminary analysis has identified a rainforest flora containing Elaeocarpaceae (*Sloanea/Elaeocarpus*), Lauraceae, Myrtaceae (*Myrtaciphyllum*), Proteaceae (*Banksieaephyllum*, aff. *Neorites*), Sterculiaceae (*Brachychiton*), Podocarpaceae (*Decussocarpus, Podocarpus*), and the fern *Lygodium*. Physiognomic analysis of the leaves suggests that the closest analogue is with Complex Notophyll Vine Forest. The Monier Golden Grove Eocene flora has some taxonomic similarity in common with other southern Australian Eocene floras, but has a distinctive character which supports the idea of a regionally diversified rainforest vegetation in southern Australia in the Eocene.

KEY WORDS: Fossil, Eocene, Golden Grove, South Australia.

Introduction

In January 1986, a fossiliferous clay lens was uncovered during sand quarrying operations at the Monier East Yatala Sand Pit in Golden Grove, South Australia (138°43'30", 34°47'10") located approximately 25 km north-east of Adelaide city centre (Fig. 1). The lens was found amidst cross bedded, fresh water sands and the entire depositional sequence suggests a meandering stream system with possible lacustrine elements.

While this is the first megafossil flora described from the Golden Grove area, other plant fossils have been reported from the region.

Eocene clays containing dispersed plant fossils have been described in several papers (e.g. Lange 1978a, 1978b, 1980), but a precise description of the location of the deposit is not given in any of them. As a recent drilling program by the S. Aust. Mines and Energy Department has indicated that the lateral extent of the new lens is extensive (Neville Alley pers comm.), it is possible that these earlier reports were based on material from the same system. However, it is known that the earlier material did not come from the Monier quarry, and hence precise geological comparison between the earlier reported material and the Monier Golden Grove Locality may never be possible. They may be palynologically correlated, however.

A preliminary palynological analysis (W. K. Harris, Western Mining Co. pers. comm.) placed the lens at the base of the *Proteacidites pachypolis* Zone of the Eocene. A second palynological analysis (Neville Alley pers. comm.) supports placement in this zone. The deposit is therefore either just younger than the Maslin Bay deposit located 30 km south of Adelaide or equivalent to it. The Monier Golden Grove deposit is slightly older than the Anglesea deposit in Victoria (Christophel, Harris & Syber 1987) (Fig. 1).

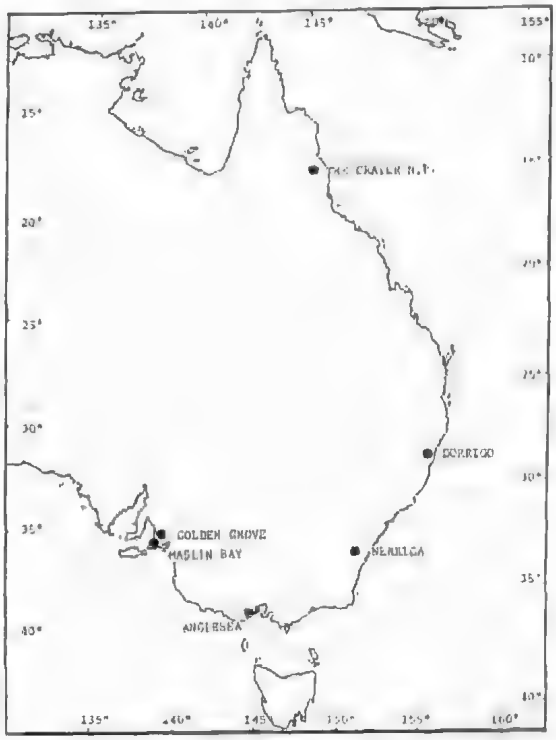

Fig. 1 Map of eastern Australia giving the location of the Golden Grove locality relative to the Eocene localities of Maslin Bay, Anglesea and Nerriga, and two of the sites from which litter was collected for the physiognomic comparison.

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Materials and Methods

Portions of the lens are highly oxidised and plant remains are preserved as brown impressions in beige matrix with no organic remains present. The majority of the lens contains carbonized remains within a grey matrix, and mummified leaves are floated from this material by placing blocks of the clay in a 2–3% hot aqueous solution of hydrogen peroxide to disaggregate the matrix. Many of these leaves are naturally translucent and can be photographed directly with transmitted light (Figs 2–6). The rest are black, opaque, and were observed and photographed with UV light to study the venation detail using the technique of Christophel *et al.* (1987). This type of preservation is shown in Figs 7–9.

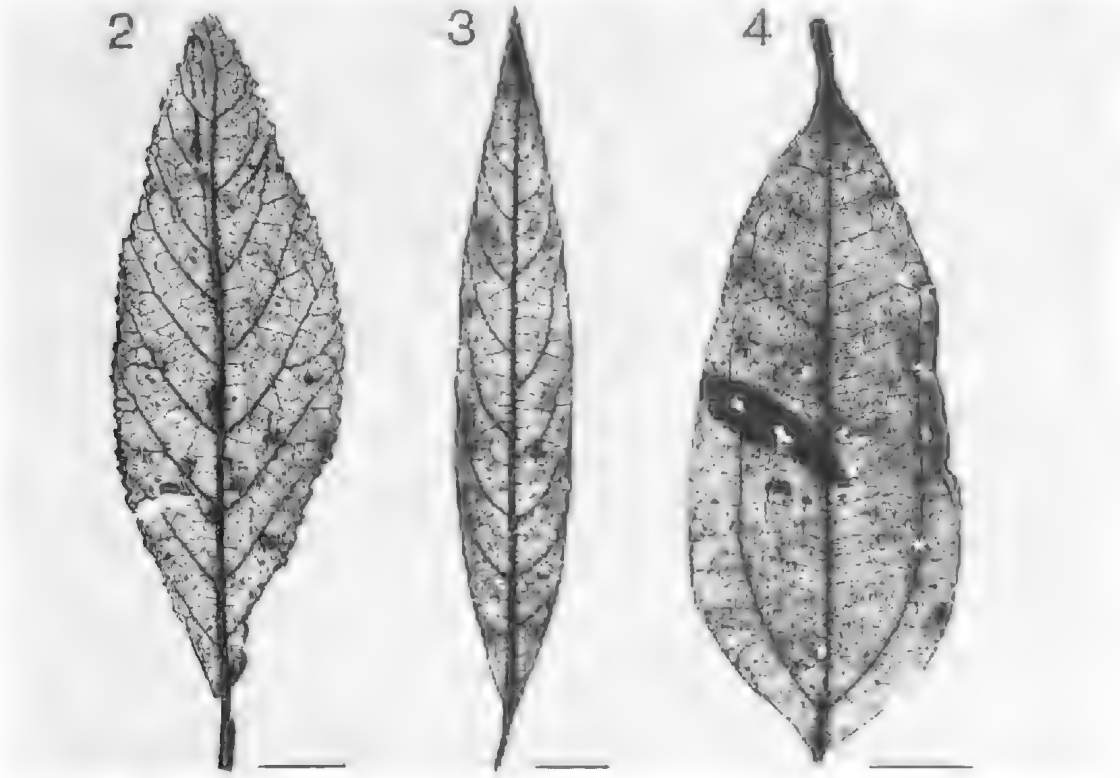
A sample cuticle is then prepared using the method discussed in Christophel *et al.* (1987) and the leaf is mounted between glass slides in Phenol Glycerin Jelly.

All leaves illustrated in this paper are housed in the Adelaide University Palaeobotany collection. Fruits and flowers obtained from the macerate are stored in 1% phenol in 50% ethanol in sealed vials, in the same collection.

Components of the Megafossil Flora

The commonest leaf taxon from the mummified horizons at Golden Grove is a serrate-margined notophyll (Fig. 2). This taxon has superficial similarities to *Sloanea/Elaeocarpus* (Elaeocarpaceae). A recent study of extant species of this family found that leaves of *Elaeocarpus* L. and *Sloanea* L. could not be separated, but that they consistently clustered distinctly from other genera in the family and from other architecturally similar families (Moira Turnbull Adelaide University pers. comm.). The Golden Grove fossils similar to Fig. 2 consistently clustered with the extant *Sloanea/Elaeocarpus* complex.

Another common taxon in the Monier Golden Grove flora is *Banksieaephyllum* Cookson & Duigan (Fig. 9). As the name suggests, the leaf is very similar to those found in the tribe Banksieae (Proteaceae), but as Christophel & Greenwood (1987) suggested, this could also represent the foliar organ of *Musgraveinanthus* Christophel (1984). This is supported by the occurrence of *Musgraveinanthus* in the Monier Golden Grove deposit, which is the only locality other than the type locality (Anglesea) from which it has been



Figs 2–4. Transparent mummified leaves from Golden Grove. Scale bars = 1 cm. Fig. 2, Elaeocarpaceae aff. *Sloanea/Elaeocarpus*; Figs 3., 4. Lauraceae.

reported. *Banksieaeidites arcuatus* Stover, the pollen type found in *Musgraveinanthus* inflorescences, is also found as a dispersed grain at Golden Grove.

The Lauraceae has been suggested as an important family in Australian Early Tertiary floras. Based on the characters discussed by Hill (1986) as diagnostic of the family, we have confirmed at least two common leaf taxa at Golden Grove (Figs 3, 4) which may be assigned to that family. The importance of the family in the Monier Golden Grove flora is therefore confirmed.

Leaves of *Myrtaciphyllum* Christophel & Lys are also frequently encountered in the Golden Grove flora (Fig. 7). However, a preliminary investigation indicates that the Golden Grove Myrtaceae leaves belong to different species than the two described by Christophel & Lys (1986).

Two leaf types collected at the Monier Golden Grove locality are known only rarely from other Early Tertiary deposits, Table 1. These are leaves of *Brachychiton* (Sterculiaceae) and the fern *Lygodium* (Schizeaceaceae). *Brachychiton* Scott & Endl. is very common as impressions in the leached portion of the lens, where it is recovered in both a three and five lobed form. Less common in the mummified portions of the lens, it has thus far only been collected in a three-lobed form from that material (Fig. 8). *Lygodium* is not only recovered as sterile pinnules (Fig. 6) but has also been collected as numerous fertile fronds. These can be seen to contain spores, which have yet to be studied and compared to their extant counterparts.

The gymnosperms are represented at Golden Grove by two genera of the Podocarpaceae, *Decussocarpus* Laubenf. and *Podocarpus* L'Herit. ex Pers. *sens. strict. Decussocarpus* twigs are common, and appear morphologically intermediate between *D. maslinensis* Blackburn, described from Maslin Bay, S. Aust., and *D. brownei* (Selling) Greenwood, from Anglesea (Greenwood 1987). It is quite likely that the three therefore represent a range of forms in one highly variable taxon. Similar variation can be seen in modern examples of the genus [e.g. *D. vitiensis* (Seeman) Laubenf., Greenwood 1987]. Golden Grove material of this species has been illustrated earlier by Christophel & Greenwood (1988).

Podocarpus leaves are less common, and while much longer, have epidermal features identical to *Podocarpus platyphyllum* Greenwood described from Anglesea (Greenwood 1987).

One further leaf type is reasonably common and has not been reported previously. These leaves are pinnately compound (Fig. 5) and on the basis of their stomatal arrangement and epidermal hair bases can be ascribed to the Proteaceae. They bear a superficial similarity to immature leaves of *Neorites* L.S.Sm.

While the identity of no other leaf taxa have been confirmed, a preliminary estimate of approximately 30–35 leaf types for the deposit is made. However, the present collection contains only approximately 400 leaves, and so the preliminary nature of the estimate must be emphasized. Four fruit/flower types have been thus far recovered, but only specimens of *Musgraveinanthus* have been identified.

Physiognomic Analysis

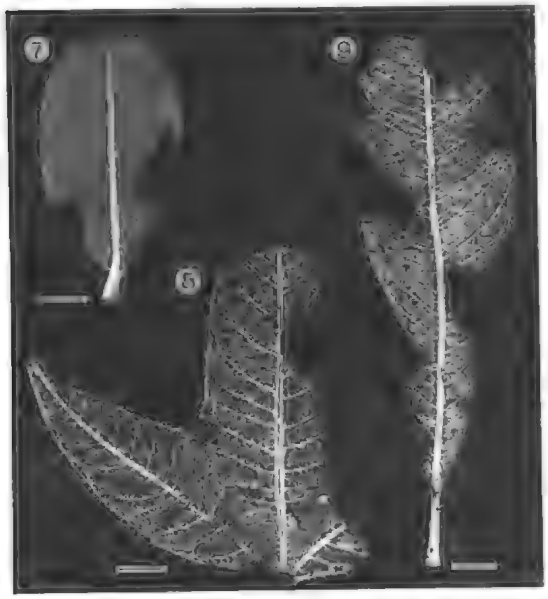
The general elliptic shape, broad lamina, and the presence of well developed 'drip tips' on many leaves (e.g. Fig. 4), strongly suggest that the Golden Grove flora was derived predominantly from rainforest vegetation. These features are often cited as being characteristic of rainforest leaves, particularly lowland tropical rainforest (Richards 1957). The presence of typical rainforest taxa e.g. Elaeocarpaceae (*Sloanea/Elaeocarpus*), Proteaceae (Musgraveinae, *Neorites*), Myrtaceae (*Syzygium*

TABLE 1. *Megafossil taxa at Australian Localities.*

Locality / Taxa	Golden Grove	Maslin Bay	Anglesea	Nerriga
Austrodiospyros	?	R	C	
Musgraveinanthus	X		X	
Elaeocarpaceae	C	?	C	?
Myrtaciphyllum	C		X	
Brachychiton	C		R	
Decussocarpus	C	X	C	
Podocarpus	X		X	
Gymnostoma		R	C	R
Zamiaceae			C	R
Lauraceae	C	X	C	C
Lygodium	C	R	X	
Banksieaephyllum	C	X	X	
Total Diversity	30–35	100+	100+	25–30

C = common (> 10%); X = present (1–10% — possibly more common, but not assessed); R = rare (< 1% of flora); ? = similar but unconfirmed.

Figs 5, 6. Transparent mummified leaves from Golden Grove. Scale bars = 1 cm. Fig. 5. Proteaceae aff. *Neorites*; Fig. 6. Fern pinnule, *Lygodium*.



Figs 7–9. Opaque mummified leaves photographed using UV light source. Scale bars = 1 cm. Fig. 7. *Myrtaciphyllum*; Fig. 8. *Brachychiton*; Fig. 9. *Banksieaephyllum*.

type), Lauraceae, Podocarpaceae (*Decussocarpus, Podocarpus*) strengthens this impression, although representatives of some of these families are also found in more open forest types. It is appropriate therefore to compare the foliar physiognomy of the Golden Grove flora to that of modern rainforest.

The use of foliar physiognomic analysis for the interpretation of fossil leaf-beds based on forest canopy data has been criticized for ignoring the effect of transportation and the differential input and preservation of leaves prior to sedimentation (Martin 1986; Christophel & Greenwood 1988). Recent research, however, suggests strongly that leaf-litter from each of the main rainforest types recognized by Webb (1959, 1968) and Tracey (1982) has a unique physiognomic "signature" and that this signature is often retained in stream-deposited leaf-litter (Christophel & Greenwood 1988). Work in progress by the second author supports this. The physiognomic features of primary importance are length, width, shape and margin type. Leaf length only will be considered in this paper, as it is sufficient to illustrate the physiognomic signature.

Fig. 10 shows the frequency distribution of leaf-length for the four main rainforest types recognised by Webb (1959, 1968) and the frequency distribution

for the Golden Grove flora using mummified leaves. As can be seen from the figure, the extant rainforest types can be clearly separated on leaf-length alone. Fig. 11 shows the same data plotted as a cumulative percentage for each length class. The CNVF (Complex Notophyll Vine Forest) forest type has been presented as two separate sites to better illustrate the intrinsic physiognomic variability of litter from NE Queensland (The Crater) and N.S.W. (Dorrigo) from this type. Standard errors for the data from these sites are presented in Table 2. These results indicate that the Golden Grove Eocene vegetation was physiognomically closest to CNVF from The Crater N.P. and less so to CNVF from Dorrigo in northern N.S.W. Dorrigo and The Crater fall within the Mesotherm seasonal Torresian zone of Nix's bioclimatic classification of Australia (Nix 1982).

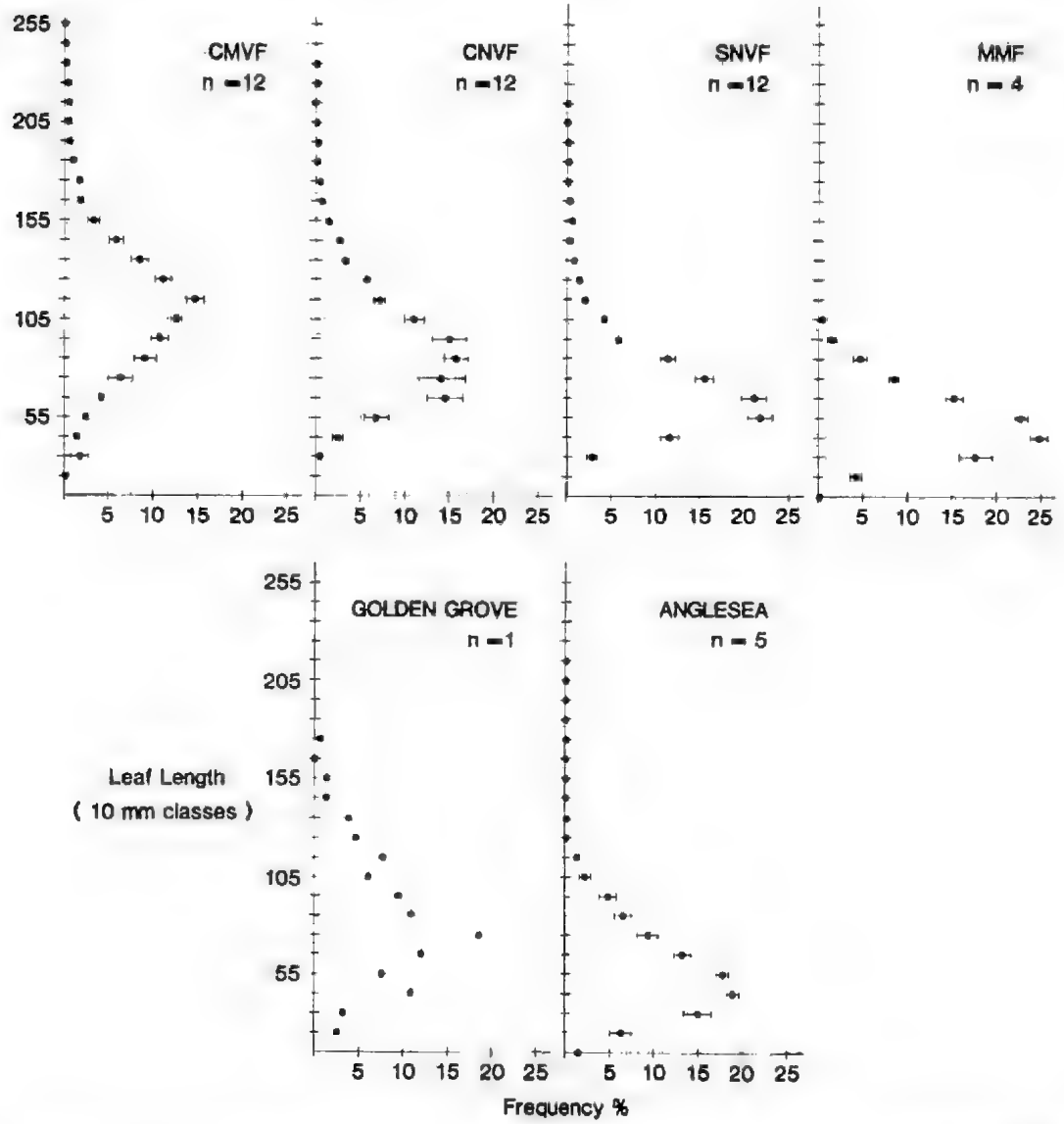


Fig. 10. Frequency distributions of leaf length (10 mm classes) for Microphyll Mossy Forest (MMF), Simple Notophyll Vine Forest (SNVF), Complex Notophyll Vine Forest (CNVF), Complex Mesophyll Vine Forest (CMVF), Golden Grove, and Anglesea. Forest nomenclature follows Webb (1959, 1968) and Tracey (1982). Each of the data sets for the modern forests is based on four samples of 200 leaves collected from litter (Christophel & Greenwood 1988). Golden Grove data are based on 156 complete leaves from the initial 1986 collections. Standard Errors are plotted.

Comparison with other Eocene Floras

As mentioned above, the Monier Golden Grove flora is similar in age to the Maslin Bay flora and is somewhat older than the Eocene Anglesea flora. It is younger than the Nerriga flora (Hill 1982) but can still be usefully compared with it, as all are Eocene. Table 1 compares the major (as well as some of the unique minor) taxa from the four deposits.

Perhaps the strongest similarities to the Golden Grove megafossil flora may be seen in the Anglesea locality. While the diversity of the Anglesea flora is shown as much higher (100+), this represents a composite of six separate fossiliferous lenses. Taken separately, the lenses at Anglesea have a diversity much more similar to Golden Grove (Christophel *et al.* 1987). The strongest links between the two are the very similar Elaeocarpaceae leaves, *Musgravelnanthus*, *Myrtaciphyllum* and *Brachychiton*. They also have in common *Decussocarpus*, *Podocarpus*, Lauraceae, *Banksieaephyllum* and *Lygodium*, but these are not restricted to those localities. Physiognomically, however, Golden Grove is interpreted as CNVF, whereas the New Site lenses at Anglesea were interpreted by Christophel (1981) and Christophel & Greenwood (1988) as being closest to SNVF (Simple Notophyll Vine Forest) from N.E. Queensland (Fig. 11).

The diversity of Golden Grove is similar to Nerriga, but there are very few shared taxa, and the only feature in common is really the shared importance of the Lauraceae. Maslin Bay has a few taxa in common with Golden Grove, but in general Maslin Bay has a high diversity with no truly common taxa, while Golden Grove has fewer, well represented taxa and hence suggests a quite different floristic association. Preliminary physiognomic analysis of the Maslin Bay flora by the second author has detected minor differences which suggest that the Maslin Bay flora was sourced from a warmer vegetation type (Greenwood unpubl.).

The absence of both the Zamiaceae and *Gymnostoma* Johnson at the Golden Grove locality is surprising considering the commonness of both at Anglesea and their presence in the other deposits. While further collecting may reveal either or both of these taxa, their absence to date may be taken as evidence that they are not major components of the Monier Golden Grove flora.

The preliminary investigation of the Golden Grove flora has revealed a vegetation typical of the southern Australian Eocene floras studied to date, in that it appears to have been sourced from a rainforest vegetation (Complex Notophyll Vine Forest *sensu* Webb, 1959, 1968) of reasonable diversity in a mesotherm environment (*sensu* Nix 1982). There are differences between it and the other documented floras of similar age, as is expected based on the temporal and spatial differences in the localities. While numerous similarities in taxa present have been highlighted in Table 1, it must be emphasized that these are similarities in natural and form genera, and there is no evidence yet (possible excluding Podocarpaceae) to suggest that

TABLE 2. *Standard Error Values for Cumulative Frequency of Length for Fig. 11.*

Length class (mm)	MMF†	SNVF†	Dorrigo*	The Crater*	CMVF*
15	0.2	—	—	—	—
25	0.7	0.2	—	—	0.1
35	2.1	2.3	0.2	1.3	2.0
45	2.3	5.5	0.9	3.7	3.0
55	2.0	6.4	0.7	3.1	3.2
65	1.4	5.3	0.8	1.4	2.9
75	1.5	3.8	1.5	1.8	2.3
85	0.8	3.0	4.0	1.2	3.1
95	0.4	3.2	3.9	1.1	4.6
105	0.2	2.3	2.2	0.9	4.2
115	—	1.6	1.7	0.9	3.7
125	—	1.3	1.3	1.1	4.2
135	—	1.0	0.9	1.5	2.9
145	—	0.9	0.6	1.0	1.8
155	—	0.6	0.5	0.8	1.0
165	—	0.6	0.2	0.6	0.7
175	—	0.5	0.2	0.5	0.5
185	—	0.5	0.2	0.2	0.4
195	—	0.4	0.3	—	0.3
205	—	0.4	0.1	—	0.4
215	—	0.2	0.1	—	0.2
225	—	0.1	-	—	0.1

* n = 4 samples of 224 leaves.
† n = 4 samples of 224 leaves for 3 sites.

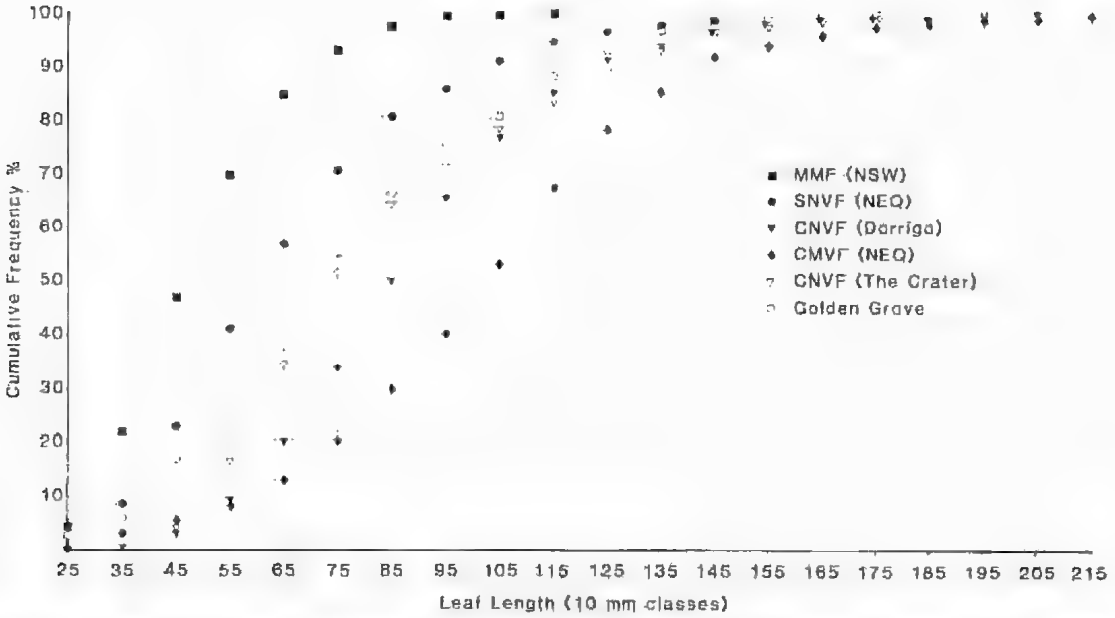


Fig. 11. Cumulative frequency histograms for the data presented in Fig. 10. Two separate localities for CNVF are given: the Crater National Park (open triangles) and Dorrigo (solid triangles). These two localities reflect the extremes of the range seen in litter samples from N.E. Queensland and N.S.W.

the same species are occurring in the different localities.

The Monier Golden Grove flora represents South Australia's only known mummified leaf flora still available for collection and study (a collection of several thousand Maslins Bay specimens exists in the Botany Department of Adelaide University, but the locality is no longer collectable), and it is hoped that further work will provide us with deeper insights into the evolution of South Australia's flora. Much of South Australia's coal reserve which is currently being considered for development is Eocene in age, and hence Golden Grove will hopefully provide a benchmark for studies of these floras when they are eventually developed.

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References

CHRISTOPHEL, D. C. (1981) Tertiary megafossil floras of Australia as indicators of floristic associations and palaeoclimate. Ch. 12, *In* Keast, A. (Ed.) "Ecological Biogeography of Australia". pp. 379-390. (Junk, The Hague.)

——— (1984) Early Tertiary Proteaceae: The First Floral Evidence for the Musgraveinae. *Aust. J. Bot.* **32**, 177-186.

———, GREENWOOD, D. R. (1988) A comparison of Australian Tropical Rainforest and Tertiary Fossil Leaf Beds. *Proc. Ecol. Soc. Aust.* **15**.

———, HARRIS, W. K., & SYBER, A. K. (1987) The Eocene flora of the Anglesea Locality, Victoria. *Alcheringa* **11**, 303-324.

———, & LYS, S. (1986) Mummified Leaves of Two New Species of Myrtaceae from the Eocene of Victoria, Australia. *Aust. J. Bot.* **34**, 649-662.

GREENWOOD, D. R. (1987) Early Tertiary Podocarpaceae: Megafossils from the Anglesea Locality, Victoria. *Aust. J. Bot.* **35**, 111-133.

HILL, R. S. (1982) The Eocene megafossil flora of Nerriga, New South Wales, Australia. *Palaeontographica* Abt B. **181**, 14-77.

——— (1986) Lauraceous leaves from the Eocene of Nerriga, New South Wales. *Alcheringa* **10**(3), 327-352.

LANGE, R. T. (1978a) Some Eocene leaf fragments comparable to Proteaceae. *J. Roy. Soc. W.A.* **60**, 107-114.

——— (1978b) Southern Australian Tertiary Epiphyllous fungi, modern equivalents in the Australasian region, and habitat indicator value. *Can. J. Bot.* **56**(5), 532-541.

——— (1980) Evidence of Lid-cells and host-specific microfungi in the search for Tertiary Eucalyptus. *Rev. Palaeob. Palyno.* **29**, 29-33.

MARTIN, H. (1986) On the Philosophy and Methods used to reconstruct Tertiary Vegetation. *Proc. Linn. Soc. N.S.W.* **107**(4), 521-533.

NIX, H (1982) Environmental determinants of biogeography and evolution in Terra Australis. Ch. 5, *In* Barker, W. R., Greenslade, P. J. M. (Eds) "Evolution of the Flora and Fauna of Arid Australia". (Peacock Publications, S. Aust.).

RICHARDS, P. W. (1957) "The Tropical Rainforest". pp. xviii, 1-450 (Cambridge Univ. Press, Cambridge).

TRACEY, J. G. (1982) "The vegetation of the Humid Tropical Region of North Queensland". pp. 1-124 (C.S.I.R.O. Melbourne).

WEBB, L. J. (1959) A physiognomic classification of Australian rainforests. *J. Ecol.* **47**, 551-570.

——— (1968) Environmental relationships of the structural types of Australian rainforest vegetaion. *Ecol.* **49**, 296-311.